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Genesis and consolidation of the Brazilian bioethanol: A review of policies and incentive mechanisms

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ABSTRACT

This article aims to investigate the introduction, sustenance and consolidation of bioethanol in Brazil. It presents an analysis of its introductory stage, from the first decades of the 20th century until the early 1970s, when, in a second stage, additional measures allowed for its consolidation and maturity, under the widely known Proalcool. The paper presents a historical reinterpretation of the policies, mechanisms and instruments adopted in both stages, aiming to highlight the economical and political links. It is concluded that the interests of the agrarian elites, operating at the political level, and the fuel supply crisis during Second World War were basic during the first stage, to sustain a productive and logistic capacity and maintain ethanol alive as an automotive fuel. It is also concluded that the launching of Proalcool represented a transition combining the interests of the sugarcane agribusiness, burdened by the drop in sugar prices, and the need to equilibrate the balance of payments due to the oil shocks of the 1970s. Ethanol supply shocks harmed its credibility and its commercial consolidation was only possible through the introduction of flex-fuel vehicles with expectations strongly relying on climate change mitigation actions.

Contents

1. Introduction

Biofuels were an option of choice at the onset of the automotive industry. However, amidst the consolidation of the second phase of the Industrial Revolution, during transition of the 19th to the 20th century, oil industry came to play a central role. Explanation for this outcome in the U.S. and for the failure to at least considering ethanol as an anti-knock additive in gasoline instead of lead, with

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clear public health advantages, has been associated to price relationships, market structures, commercial arrangements and practices combining interests of oil, chemical, and automotive industry, linking Standard Oil, Du Pont and General Motors [1]. Further investigation can explore lines of net energy balances and economic rent generation associated with oil and biofuel productive chains. Such field of investigation acquires renewed interest nowadays, amidst the debate over biofuel production potential as viable substitute for oil and its impact on food production.

The use of alcohol as a fuel is recorded since the 19th century. Before the discovery of oil, the alcohol was widely used as illuminant. Actually, alcohol substituted expensive whale oil in the U.S., when the kerosene oil still had not been invented [2]. In fact, ethanol was used to fuel Model T Ford, which was originally designed to operate on it, in 1908, and even before in agricultural machines [3,4]. Model T and Model A Fords were later designed to operate on alcohol, gasoline or a blend of alcohol and gasoline, becoming the precursors of flex-fuel vehicles. The use in motors and specifically, in the "new" automotive engines, was extensively studied also in France and Germany [5,6], and their results served as starting point for the Brazilian experiment. Ever since a dispute between fossil fuels x renewable fuels was established, as reported by Monier-Williams (1922) [5]:

> Although at the present moment there would seem to be an over-supply of petrol, and consequently little inducement to explore the possibilities of a substitute, we have no assurance that this is likely to be a permanent condition of affairs. On the contrary, there are many indications that, with the revival of industrial prosperity, the demand for motor fuel will again tend to outstrip the supply. Opinions are somewhat sharply divided as to the extent of the world's petroleum reserves, and in default of some definite evidence as to the sufficiency of future supplies, it is clearly of importance to investigate the possible alternatives

The concern about climate change, due to the increased concentration of greenhouse gases in the atmosphere, substantially originated from fossil fuels, turned attention to biofuels again, this time as a mitigation alternative of global interest, despite experience at commercial scale being limited to a few countries. In developing countries biofuel programs have also been considered due to the potential of improving the balance of payments and to promote social inclusion through the generation of employment and income in poor rural areas. The Brazilian experience with renewable fuels, particularly ethanol, goes also back to the beginning of the twentieth century. The main motivation for the establishment alcohol fuel segment was primarily the policy to strengthen the activity associated to sugar production, then of major importance to the country's economy. Since then, stimulation of production and use of ethanol as vehicle fuel was progressively strengthened by a legal and institutional framework. Most of the investigations have focused on Proalcool (National Program of Alcohol), however, the program was built from the improvement and deepening of incentive policies that had been in force since 1931 and resulted from the effort of the sugarcane industry to maintain its profitability.

This paper assesses these experiences, summarizing the trajectory of legislative policy for the promotion and incentives applied, as well as the results obtained. Specifically, it examines two phases well characterized: before and after the two oil shocks, seeking to the economical and political nexus that determined the adoption of those measures in the two phases. The granting and subsequent removal of government incentives for the deployment, development and consolidation of ethanol during Proalcool (1975–2007), which have worked as a worldwide reference for newer initiatives, are also assessed. This study compiled and analyzed the information available from agencies involved in formulation and implementation of agricultural and energy policies in Brazil: the Ministry of Agriculture, Livestock and Supply (MAPA[1]), the National Petroleum Agency (ANP[2]), the Ministry of Mines and Energy (MME[3]), among others.

2. The period before the oil shocks

The use of fuel alcohol in Brazil was, since its beginning, strongly linked to the production and trade of sugar which, as one of the main products of export of the country since the colonial period, was always important to provide economic stability. Therefore, the promotion of the sugarcane alcohol as a fuel had, at first, a more significant paper as a buffer for protecting producers from sugar price fluctuations than as instrument of technological innovation or opening of new commercial borders. Inspired in experiences carried out in Europe and in the U.S., the Northeastern agrarian elites undertook, since the first decade of the 20th century, the initial experiments with the fuel alcohol, starting from German technology and equipments, being successful in nationalizing them. In 1927, the first economically viable product, the alcohol-motor USGA (Serra Grande Alagoas Plant)[4] was thrown commercially in Alagoas state. These experiments represented an attempt to overcome the stagnation of the sugarcane sector due to the loss of external market ensued since the 17th century, as well as First World War crisis, that culminated in the Great Depression [7–9].

From the end of the 19th century, the position of the sugar industry of Brazil in the external trade was influenced by factors as the ascension and decadence of beet sugar in the international market; commercial treaties anti-subsidies and the periods of shortage and overproduction among First World War, the 1929 stock market crash and Second World War. In the first decades of the 20th century, the internal market grew in importance, surpassing exports of the product. At the same time, the technological expansion impelled by the coffee industry induced the innovation search also in the sugar sector, marked by the craft production and with competitiveness lower than other exporting countries of Latin America. With the new regional labor division in the country, that moved the productive axis to the Center-South, the production of sugar lost importance, maintaining primacy as economic activity only in the Northeast area, as it happened since the colonial period. On the other hand, the warmed economy of the Center-South, with capital readiness, technology and demand, attracted the installation of new capacity for sugar production, in the consuming center itself, which started to compete directly with the Northeast producers.

The first instruments of state intervention in favor of a sugar-alcohol industry in Brazil, established in that conjuncture, were based on production diversification – resulting in significant impulse to the research of the automotive use of the ethanol – and establishment of pre-set volumes of cane production and of sugar with administered prices (Table 1). These instruments have sought to minimize the effects of overproduction in the period immediately following First World War, produced mainly by the downturn in international demand for sugar [10]. The Experimental Station of

[1] Abbreviation in Portuguese for Ministério da Agricultura, Pecuária e Abastecimento.

[2] Abbreviation in Portuguese for Agência Nacional do Petróleo.

[3] Abbreviation in Portuguese for Ministério das Minas e Energia.

[4] Automotive fuel composed by 75% ethanol and 25% of ethyl ether. In 1929, 500 cars used in the Northeast, in addition to the USGA, other ethanol-based fuels known as AZULINA, MOTORINA... In April 1933 operated the following USGA pumps: 3 in Recife; 1 in Caruaru; 1 in Garanhuns; 2 in Maceió; 1 in Serra Grande; 1 in União dos Palmares [8].

Table 1
Incentives before Proalcool.

1910–1932	
Decree 10076/1913	Regulates the experimental stations of sugarcane and the Experimental Station of Campos.
1926	The sugar mill owners and cane growers of Pernambuco state founded the Defense Institute of Sugar and Alcohol to encourage the use of alcohol as fuel.
1928	Creation of the General Plan of Defense of the Sugar, the Cane Spirituous Liquors and Alcohol: aimed at disciplining the activities of the sugarcane industry into cooperatives.
Decree 19717/1931	Addition of 5% to imported gasoline. Required the consumption of fuel with at least 10% of alcohol in cars owned or the service of the Union, States and Cities. The material required for installation of plants for the production and distillation of ethanol was exempted from taxes and import duties.
Resolution MA 04/08/1931	Created CEAM.
Decree 20356/1931	Established technical standards for the production of anhydrous alcohol supervised by the Office of Audit under the Ministry of Agriculture.
Decree 20761/1931	Created CDPA.
Decree 21201/1931	Authorized the Ministry of Agriculture to sign contracts with private entities for the implementation of anhydrous ethanol distilleries and grant tax incentives.
Decree 22152/1932	First to include both sugar and alcohol. Limited the production of sugar and created new incentives for the production of alcohol.
1933–1941	
Decree 22789/1933	Created IAA.
Decree 22981/1933	Started a program to install three large central distilleries to the production of ethanol. IAA would cover 50 of the capital.
Decree 23664/1933	Regulated the promotion of alcohol fuel and its blends.
Decree 23837/1934	It reiterated previous measures of mandatory alcohol consumption by vehicles owned or in the service of the Government. Determined the preference for alcohol, to any other fuel, on equal terms, prices and quantities and the reduction of road charges for the transportation of alcohol.
Law 432/1937	Exemption from import duties for the casks and containers for the transport and storage of anhydrous alcohol.
Decree-Law 737/1938	Blend mandatory on national territory; no cap to blend level.
Resolution 003/1939	Provided for the submission of projects to obtain financing of the IAA for the assembly or expansion of private distilleries.
Resolution IAA 21/02/1941	Raised to 20% the minimum blend of anhydrous ethanol to gasoline that was previously only 5%.
Decree-Law 3855/1941	Promulgated the Statute of Sugarcane Production.
1942–1949	
Resolution IAA 031/1942	Established the Plan of the War Economy.
Harvest Plan 1942/1943	It destined the maximum from available raw material for the production of alcohol. Extended the period of production of anhydrous alcohol distilleries to 250 days.
Resolution 034/1942	It adopted the Development Plan of alcohol. Defined the use of anhydrous alcohol for fuel and hydrous alcohol for other purposes.
Resolution IAA 03/1942	Approved the Plan for the Control of Alcohol Production.
Decree-Law 4722/1942	Stated the alcohol industry of national interest. Established guaranteeing minimum prices for alcohol and for raw materials to manufacture for four years.
Decree-Law 9827/1946	Determined the general review of quotas for sugar production allocated to each state, proportional to their consumption.
Resolution IAA 154/1948	It created the Compensation Fund of Sugar Prices.
Decree 25174-A/1948	Determined the expansion of storage facilities for molasses and alcohol and most of the transportation from the producing regions to the mixing centers and consumption.
Resolution 210/1948	Created the Fund for Anhydrous Alcohol.
1950–1959	
Resolution 489/1950	Granted a special bonus for ethanol producers.
Resolution 501/1951	It fixed 10% of the general quota of the production of sugar for manufacture of direct alcohol.
Resolution 619/1951	Differentiated pricing policy for sugar to enhance the competitiveness of the Northeast.
1952	National Plan for Cane Spirituous Liquors.
Resolutions 703/1952, 806/1953	Promoted the establishment of private autonomous distilleries.
Resolution 1284/1957	Established a new system for increasing the production of sugar and annual quotas for direct alcohol.
Resolution 1380/1959	Instituted for the first time a harvest plan stating that sugar production was lower than the previous year.
1960–1968	
1963	Created the Expansion Plan of the Sugar Industry that aimed to achieve a production of 100 million bags of sugar in 1971 and the installation of 50 new plants.
Law 4870/1965	Established a new benchmark for planning in the sugar sector.
Decree 59033-A/1969	Created GERAN.
Decree 59190/1966	Established a minimum of 5% and maximum of 25% for the alcohol blend.
Resolution 1974/1966	Decided on the marketing of sugar in the domestic market, dividing the country into 2 sugar regions.
1969–1974	
IAA Board Act–29/07/1971	Institutionalized the National Program for Improvement of sugarcane, administered by Planalsucar.
Decree-Law 1186/1971	Grant incentives for merger and relocation of industrial sugar facilities and other provisions.
Decree-Law 1266/1973	Created the Program for the Rationalization of Sugar Industry (later Support Program for Sugar Agro-industry).
Act IAA 59/1973	Set standards for the export of molasses and protected the alcohol production for the domestic market.

Fuels and Minerals (EECM[5]), established in 1921 in Rio de Janeiro, under the Ministry of Agriculture, Trade and Industry (MAIC[6]) as a body attached to the Mineralogical and Geological Service of Brazil, tested the feasibility of using ethanol as a fuel in spark-ignition engines either pure or blended with gasoline. The pioneer experiments carried out by EECM aimed to provide technical basis for drafting legislation, with the ultimate goal that through the use of ethanol as a fuel the sugar surplus would be absorbed. These experiments were also motivated at that time by the possibility of reducing imports of gasoline and improving the balance of payments. The tests were successful and thus supported measures taken in 1931, namely the mandatory addition of a

[5] Abbreviation in Portuguese for Estação Experimental de Combustíveis e Minerais.

[6] Abbreviation in Portuguese for Ministério da Agricultura, Indústria e Comércio.

minimum of 5% ethanol to imported gasoline [11–13]. In 1934, the EECM was incorporated as National Institute of Technology (INT[7]) and became part of the structure of the Ministry of Labor, Industry and Commerce (MTIC[8]) [14].

Despite all efforts, there were many conflicting interests to promote the production and use of ethanol as fuel. So referred Barbosa Lima Sobrinho (1943) [15] this subject:

> It was never thought to produce alcohol to meet the total requirements of fuel in the country. It was attempted only to get part of the fuel that Brazil needed. The idea of eliminating the import of gasoline did not seem prudent, when it was felt that we had balance in trade with the United States, notably the biggest buyers of our coffee.

The sugar industry in Brazil was marked by economic and technological inequality evident in its large, medium and small units. The largest and most modern, concentrated in the Center-South, were the only ones with enough competitiveness to supplant state intervention, adopting both production volumes and prices autonomously. In this context, the government of Getúlio Vargas was essential to ensure the interests of the industry against the hegemony of coffee industry elite. His programs not only intensified the policy of diversification of production and control of volumes and prices of raw material (sugarcane) and finished products (sugar and ethanol), and established the mandatory use of ethanol as a fuel for automotive vehicles as part of state intervention (Table 1). Such intervention, which remained almost unchanged until the 1960s and was responsible for growth and diversification of the sugarcane industry in Brazil, was asserted by the agents in the industry (from producers of raw material up to suppliers of end product). The reasons for complaining were the significant idle capacity, particularly in the Northeast – in rapid decline, exacerbated by the crisis of 1929 and the supremacy of the Center-South industrial park – as well as great surpluses with neither external nor internal demand that projected an impending collapse [10].

In 1931 were established both, the Commission of Studies on Alcohol-Engine (CEAM[9]) under the Ministry of Agriculture (MA[10]), to evaluate the viability of ethanol as a fuel and as an additive to gasoline, and a Defense Committee of Sugar Production (CDPA[11]), under the Ministry of Finance, to reconcile the interests of producers of sugar, cane growers, traders and consumers [16,12]. IAA (Institute of Sugar and Alcohol) was created in 1933 through the merger of the CEAM and the CDPA, initially subject to the MA and, as of 1960, to the newly established MIC (Ministry of Industry and Trade) [17,18]. This body had great importance for the energy policy of ethanol fuel, and alcohol sector, even after Proalcool. Its primary function was to regulate and supervise the activities of the sector, acting as a funder, but at the beginning, its goal was to keep sugar prices at an appropriate level by buying the production surplus [19,20]. The direct functions of the IAA were the installation and operation of distilling plants[12], the marketing monopoly of anhydrous ethanol, the pricing for purchase and sale of ethanol and the establishment of limits for the production of ethanol and sugar in mills; and technical and financial assistance to plant owners. The Institute was enabled to propose to the Finance Ministry and state and local governments, changes in taxes and fees to protect the sugar–alcohol industry. It could also produce ethanol from sugar whenever it had the necessary infrastructure [21].

The existence of the IAA produced, however, a contradiction in the field: by eliminating the risk in farming and promoting price stability, it propitiated a strong vertical integration and concentration of activities of the sugarcane industry around the mills. As a result, sugarcane farmers, especially those in semi-feudal pattern, were gradually being driven out of their economic activity [22,23]. One of the measures attempted by the State to organize the relations between industry players, usually integrated (from raw material to final product) and hegemonic and agents exclusively agricultural (sugarcane suppliers) who wanted to maintain market share in order to keep their source of income and their land, was the establishment in 1941 of the Statute of Sugarcane Production, still in force. On this measure observe Carvalho et al. (1993) [16]:

> To regulate relations between factory owners and suppliers, was established in 1941 the Statute of sugarcane production, with the primary goal of cementing the portion of the sugarcane suppliers as co-participants in the complex production process. It ordered that the mills could not grind more than 60% of its own sugar.
>
> Since then, the legislators expected the sugarcane agro-industry to reverse its structure with the separation of agricultural and industrial activities, but this was never effected.

In 1938 the National Petroleum Council (CNP) was created, originally subordinated to the Presidency, and then incorporated into the Ministry of Mines and Energy, when it was established in 1960. Its prime role was to establish the pricing of fuels, especially for oil derivatives, but interfering also in the ethanol policy.

The Second World War was fundamental in the development of sugar industry in Brazil. The whole situation of the ten years before the war was unfavorable for the success of the ethanol fuel industry in Brazil. But suddenly, the "álcool-motor[13]" became perceived as indispensable, which valued the ethanol park. The scarcity of petroleum products, especially gasoline, which was mostly imported, impacted positively the value of the ethanol industry. The production cost of fuel ethanol was prohibitive, even internationally, as observed by Lima Sobrinho (1943) [15], quoting Commonwealth Fuel Advisor, Australia: (.) "The manufacture of alcohol to replace gasoline is uneconomical and can only be justified by considerations of national and social character, to be mixed with gasoline, at a rate of about 15%" [15]. Some of the factors that explain this high cost were the technological stage for the production of ethanol: agricultural productivity was low and industrial facilities, virtually non-existent, and rudimentary. The expectation of lower prices was unreal. Even so, the level of price exercised at the beginning of that period was only possible due to the prevailing use of molasses[14] as raw material instead of

[7] Abbreviation in Portuguese for Instituto Nacional de Tecnologia.

[8] Abbreviation in Portuguese for Ministério do Trabalho, Indústria e Comércio.

[9] Abbreviation in Portuguese for Comissão de Estudos do Álcool Motor.

[10] By Decree 19448/1930, the Ministry of Agriculture, Trade and Industry was renamed the Ministry of Agriculture and by Decree 19433 of 1930 was created the so called Ministry of Labor and Industry Trade.

[11] Abbreviation in Portuguese for Comissão de Defesa da Produção Açucareira.

[12] They were not linked to any particular mill, but were equipped to process the raw material forwarded by those who did not have its own distillery, or whose distilleries were too small. The first was installed in 1933 in Campos-RJ, the second in Cabo-PE and another in Ponte Nova-MG. The plant of RJ aimed to absorb the excesses of cane production, the one of PE, to regulate the internal market of sugar and make better use of sugar molasses and finally, the one of MG, to regulate the excess of canes through mills [15].

[13] Expression that since the 1920s designated the fuel containing alcohol.

[14] Liquid obtained as residue from the manufacture of crystallized sugar, resulting from centrifugation of B Mass, containing part of ATR and non-crystallized sucrose [25]. ATR is the abbreviation in Portuguese for Açúcar Total Recuperável (Total Recoverable Sugar). ATR corresponds to the amount of sugar available in the raw material minus the losses in the manufacturing process, and prices of sugar and ethanol plants sold by the domestic and foreign markets [26]. B Mass is a blend of sugar crystals and its corresponding juice (honey) from which the crystals were obtained, resulted from A Mass (original juice) decoction.

sugarcane "primary juice"; otherwise the cost would be higher. However, exactly in this opportunity, the production from sugarcane, which was very rare, began to be increased. Gasoline, then scarce, had its manufacturing costs about 7–10 times smaller than those of ethanol [5] and to compete with it in this scenario was only justified in face of a period of exception.

Ethanol fuel had already secured a role as regulator of the profitability of the sugar industry. The decree imposing the blend was in force, and yet there was no intention to adopt the use of pure ethanol, even in the context of war, for several reasons. From the macroeconomic point of view, there was no interest in provoking trade retaliation by the U.S., which alone bought 1/3 of national exports, whose main product was coffee. The coffee elite also had no interest in such imbalance and could create antagonistic political pressure. The main raw material used, the molasses was not sufficient to meet the needs of both industry and the full substitution of gasoline for the national automotive fleet and, on the other hand, the processing priority for the cane was sugar. The "álcool-motor" was entirely tax free. In case of total replacement of petrol, the taxing would be inevitable, leading to a retraction in consumption, which was undesirable [15].

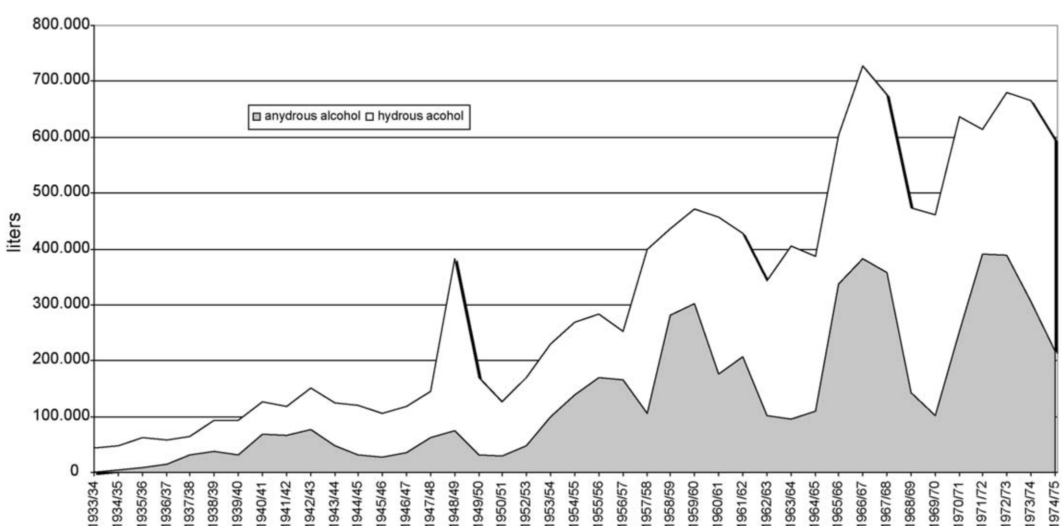
Since the use of pure ethanol had never been in question, the tests carried out since the 1920s had already determined the optimal blend for the Brazilian fleet at around 10%. This parameter was established because it would be acceptable to all brands of engines in use in the country. However, the limits were very broad, ranging from almost 0% to 25% [24]. It must be emphasized that the fuel used in "álcool-motor" refers to anhydrous ethanol, whose development was enthusiastically promoted by local technicians. This fact is peculiar because, as narrated by Lima Sobrinho (1943) [15]: "When the Institute of Sugar and Alcohol was created, there was in Brazil only one apparatus for the manufacture of anhydrous ethanol. It could produce 5000 daily liters of alcohol, but it had not begun to work". In 1943, the production exceeded 700,000 daily liters. This increasing trend, despite variations, is showed in Graph 1.

The role of IAA was essential in the process of expanding the use of automotive ethanol. This action occurred not only as a financial agent for the sector through the provision of incentives and investment with own resources but also as a planner, executioner and operator of the production policy of the fuel through the construction and operation of distilling plants, of its own property. The agency also implemented a distribution logistics which included the collection of ethanol directly from producers, transportation to the oil companies or distributors and even advance payments for the product, although the price could be slightly lower in this case.

Despite all the stimuli, the production of anhydrous ethanol was insufficient to meet the needs during the war. A series of plans were designed to minimize the contingencies of war and rationing of ethanol consumption as fuel [19] (Table 1). The growth trend since 1933 began to decrease from the 1942/43 harvest. Dehydrating products, mostly imported, necessary for the processing of hydrous ethanol, were lacking [19]. Submarine warfare also hindered coastal transport important for the trading of goods, including sugar, creating an unmet demand in the Center-South, from the Northeast [19]. This prompted investments to increase production of sugar in the very consumer center, putting ethanol in the backstage.

Sugar production rose again, in the 1946/1947 crop. However, the conditions of international trade were unfavorable. The production of ethanol directly from sugarcane was encouraged, to appropriate the surplus of sugar, but without success. With the accumulation of deficits in the payments balance and decline of foreign exchange reserves, the government adopted new measures to assure stability and improvement of the technical patterns of ethanol industrial park (Table 1). It was an attempt to give new impetus to the development of the manufacturing of ethanol fuel and to expand consumption in the country. As a result, the 1948/1949 crop sugar production reached a record high, giving IAA the flexibility to decide whether to export the surplus, or to destine it to the manufacture of ethanol [19].

The 1950s were characterized by expansion of industrial sugarcane. In the beginning, any surplus sugar was exported or intended for the production of "direct alcohol" (obtained from sugarcane juice), or "residual alcohol" (obtained from molasses). However, there was an unsatisfied demand for anhydrous and hydrous ethanol that the IAA has tried to overcome ensuring a quota of sugar for its manufacture, promoting the production of ethanol by concentrating the cane spirituous liquor and the installation of private autonomous distilleries (Table 1). In addition, the sugar industry was also encouraged, initially, with pricing policies favorable to Northeastern producers in the Southern markets and later, increasing the share of global sugar production in the country. In the second half of the 1950s, producers of the Center-South, especially in Sao Paulo, were for the first time allowed to increase its installed capacity, while the surpluses of Northeast were directed for export. The result of these measures was an overproduction of sugar only slightly balanced in



Graph 1. Alcohol Production in Brazil 1933–1975 (l/crop). *Source*: [15,19,27].

1957, when the annual quota system for the direct alcohol was initiated (Table 1). From the 1959/1960 harvest onwards, the planning started to consider domestic consumption and sugar export obligations, normalizing the situation. From the 1960s, the preceding expansionist policy of the IAA changed, focusing the concentration and modernization of the sector in order to mitigate the effects of sugar overproduction in the period and increase its external competitiveness, enabling the exports of the product. At the end of the decade, the transition of sugar–alcohol production axis to the Center-South was complete [19].

The Cuban revolution and the subsequent cancellation of sugar exports from Cuba to the United States led to an expectation of increase in sugar exports from Brazil; in the expansion of industrial capacity; in the sugar plantations and in foreign markets for ethanol, whose consumption had been declining because of the expansion of oil refining capacity of Petrobras, established in 1953 [19]. Thus, in 1963, the MIC (Ministry of Industry and Trade) established the Directive Program for the Policy of Cane and Alcohol[15], later called the Expansion Plan of the National Sugar Industry, which recast the ethanol policy, according to the expected increase in sugar production and in the quantities of molasses, destined to produce residual alcohol (Table 1). In 1965, there was a decrease in absolute and relative prices of sugar, discouraging exports [19]. In 1966, the government established a minimum (5%) and a new cap (25%) for blending with gasoline [28].

From the 1970s, investments of the IAA turned to the expansion of productive capacity and efficiency of industrial processes and to increase crop productivity, using resources from the Special Fund for Export. This fund, created in 1965, was formed from the appropriation of income from the sale of sugar in the international market by the IAA and its purchase at a much lower price in the domestic market. In addition to the Special Fund for Export have been created: the Fund for Rehabilitation of Sugarcane (FDR[16]) in 1961, which was abolished only in 1991, managed by the Ministry of Agriculture; Fund for Rationalization of the Northeast Sugarcane Industry (FURAGRO[17]) in 1968, managed by the Ministry of Interior/Superintendency for the Development of the Northeast (SUDENE[18])/Special Group for Rationalization of Sugarcane Industry in the Northeast (GERAN[19]); the Fund for the Support Program to the Sugar Industry (FUNPROÇUCAR[20]) in 1973, managed by the Ministry of Industry and Trade/IAA. In the same period were created: the National Plan for Improvement of Sugarcane (PLANALSUCAR[21]), linked to the IAA in 1966, but that actually entered in operation only in 1971 [29–32]; the Program for the Rationalization of the Sugar Industry, also linked to the IAA in 1971, replaced by the Support Program for the Sugar Industry in 1973 [33,32] and, at last, Proalcool, in 1975.

3. The Proalcool phase

In the period between the two oil shocks the Brazilian energy policy was reviewed with the aim of promoting the reduction of import of petroleum and its derivatives, which amounted to 76.9% of the total consumption. Off-shore oil exploration program was launched. Oil products substitution programs, on incentive and mandatory basis, were designed and implemented: coal for fuel oil; vegetable oil for diesel oil; replacement of gasoline with hydrous ethanol in adapted vehicles and reduction of gasoline consumption by the addition of anhydrous ethanol. Expansion of electric power generation capacity through building new hydro power plants was planned and the Brazilian Nuclear Program was launched. Among these, the initiatives that were successful were the hydraulic capacity expansion, the Proalcool, and the off-shore exploration and production.

The success of Proalcool resulted from a combination of factors. As discussed, the country consolidated an industrial and agricultural base for the production of sugar; however, it soon started to face a new surplus of sugar production and low prices due to unfavorable conditions in the international markets. High oil prices, from the first oil shock, increasing problems for the balance of payments. While the main basis and focus of the Proalcool was the large-scale sugarcane agro-industrial complex, in its initial stage, the Program also included the possibility of producing ethanol from cassava and sugarcane from small scale and decentralized family farms[22], combined with food production. However, soon the sugarcane monoculture has become hegemonic in the production of ethanol.

The creation decree (Table 2) established that the Proalcool would be managed by the MIC through the National Commission of Alcohol, created in the same act. The functions of capturing proposals for the modernization and expansion of distilleries to be submitted to the Commission, to establish the base price for the molasses, to promote the export of molasses or ethanol of any kind, to establish technical specifications for the molasses and ethanol of any origins remained with the IAA. The CNP was responsible for ensuring parity prices of anhydrous ethanol (for blending with gasoline and chemical industry) and sugar (for other purposes, the IAA determined the price parity). It was also responsible for ensuring the sale of anhydrous ethanol for fuel purposes, through the coordination of a distribution plan to be implemented with the distributors of petroleum [35].

Table 2
Characteristics of National Program of Alcohol.

Proalcool Decree no. 76.593/1975
Goals
• Equilibrium in balance of payments with the reduction of dependence on foreign oil.
• Diversification in the use of sugarcane (to take advantage of the availability of surplus).
• Expanding of production of capital goods.
• Reducing regional and individual income disparities.
Current situation and prospects
• 27.5 billions liters of alcohol (anydrous and hidrated) produced in 2008, fully from sugarcane. 5 billions exported [26].
• Renewable energy accounts for 45.9% of the domestic supply in Brazil (hidropower 14.9%, firewood and charcoal 12.6%, sugarcane derivates 15.9%) [36].
• The growth in sugarcane derivatives is expected to be accompanied by the diversification in its use.
• Technology improvement and diversification of use of biomass expected. Brazilian of flex-fuel vehicles fleet to grow up to 30% by 2010 [37].
• R&D on second generation fuels (lignocellulosic biomass to ethanol).
• Commoditization of ethanol.

[15] This plan was also motivated by the agency of GERCA - Executive Group for the Rationalization of Coffee Culture of the Federal Government, which sought to diversify activities in the areas where the coffee had been eradicated.

[16] Abbreviation in Portuguese for Fundo de Recuperação da Agroindústria Canavieira.

[17] Abbreviation in Portuguese for Fundo de Racionalização da Agroindústria Canavieira do Nordeste.

[18] Abbreviation in Portuguese for Superintendência do Desenvolvimento do Nordeste.

[19] Abbreviation in Portuguese for Grupo Especial para Racionalização da Agroindústria Canavieira do Nordeste.

[20] Abbreviation in Portuguese for Fundo para o Programa de Apoio à Agroindústria Açucareira.

[21] Abbreviation in Portuguese for Programa Nacional de Melhoramento da Cana de açúcar.

[22] Silva et al. (1978) [34], still in the stage of implementation of the program, examined energy requirements to produce ethyl alcohol from three different crops, cassava, sweet sorghum, and sugarcane concluding that the best energy balance was for the latter.

In 1979, the Federal Decree 83700 created the National Council on Alcohol (CNAL[23]), replacing the National Commission of Alcohol, chaired by the same MIC and the National Executive Commission of Alcohol (CENAL[24]). The CNAL formulated policy and set the guidelines for Proalcool while CENAL was the executive body of CNAL, responsible for technical and administrative support. CNP and IAA basically kept their assignments. The CNP, in addition, proposed price of ethanol fuel at the pump and distributors and managed resources from the sale of ethanol fuel [38].

The IAA was dissolved by Acts 8028 and 8029 in the administrative reform of 1990, marking the liberalization of the Brazilian sugar and alcohol sector [39,40]. In the same year, the former CNP was extinguished and the National Department of Fuel (DNC[25]), which became the responsible for the regulation of the sector in Brazil, was created, by Decree-Law 99180, under the Ministry of Infrastructure. Many of the functions performed by the IAA were passed on to the DNC. The pricing and control of fiscal and credit policies have been delegated to the Ministry of Economy, Finance and Planning. The supervision, coordination and standardization of sugar–alcohol activities were taken by the Secretariat of Regional Development (SDR[26]), linked directly to the Presidency [41,42], through the Department of Sugar-alcohol Issues (DAS[27]) [43]. In 1993 the Interministerial Commission of Alcohol (CINAL[28]) was created to regulate, define and create policy instruments for ethanol fuel. The committee coordination was in charge of the MME. Among the ministries that composed the CINAL was the Regional Integration Ministry (MIR[29]), which was created by Law 8490/1992 to replace the functions of the SDR and incorporated the DAS. In 1995, the MIR was abolished and the former DAS was replaced by the Department of Sugar and Alcohol (DAA[30]), reporting to the Secretariat of Base Products (SPB[31]) of the Ministry of Industry, Trade and Tourism (MICT[32]) [44,45].

Law 9478/1997, the "Petroleum Law", marked the liberalization of the oil, natural gas and oil products in Brazil [46]. Its enactment provided a number of changes in the institutional structure of the sector and, in addition, in the policy formulation of prices and subsidies in order to facilitate the opening of the domestic market. The Interministerial Council of Sugar and Alcohol (CIMA) was created in 1997[33] [47] to deliberate on policies relating to the ethanol sector activities. CIMA was chaired by MICT until 1999, when the Decree 3159/1999[34] transferred its command to the Ministry of Agriculture and Supply (MAA[35]) [48,49]. This Council is responsible for defining the participation of sugarcane derivatives in the national energy mix and for the mechanisms aimed at economic self-sustainability of the sector. CIMA also has the legal power to set the percentage of anhydrous ethanol in gasoline.

Before the deregulation of the segment of the liquid fuel by Law 9478/1997, the structure of industry was public monopoly, whose behavior was driven by security of supply and whose performance was totally influenced by inflation control policies. After 1990, fuel prices began to reflect the costs of production, distribution and marketing of refiners, distributors and retailers, respectively. Since January 2002, the fuel sector is operated under free market regime. Prices are liberalized at refinery and import is authorized to chartered companies. Vertical integration between wholesalers and retail distributors is not allowed. Prices and margins are fully liberalized. Despite the liberalization, Petrobras remains hegemonic. The company is responsible for more than 99% of the production, refining and imports of petroleum and derivatives, but for less than 34.3% of the retail market, through an independent subsidiary company that is not entitled to any privilege when compared to other retailers. Ex-refinery prices set by Petrobras do not follow the volatility of the international market. They are adjusted by Petrobras to reflect the consolidated trends of the opportunity cost, defined by the import prices' parity. When above the opportunity cost, the prices are reduced to face threats of loss of market to imports. When below the opportunity cost, prices are raised to avoid prolonged losses of revenue. This case resembles the classical situation of a contestable market outcome, where the incumbent (quasi-monopoly, in this case) behaves competitively to avoid the threat of hit-and-run entry by new entrants in the market [50]. The processes of deregulation of the sugar–ethanol sector and fossil fuels occurred concurrently. In the new dynamic, the state has no control either of the production or exports of ethanol, but kept mechanisms to influence the market by regulating the proportion blended into gasoline and through regular purchases and sales of strategic fuel inventories. Usually such mechanisms are used to stabilize prices in favor of producers.

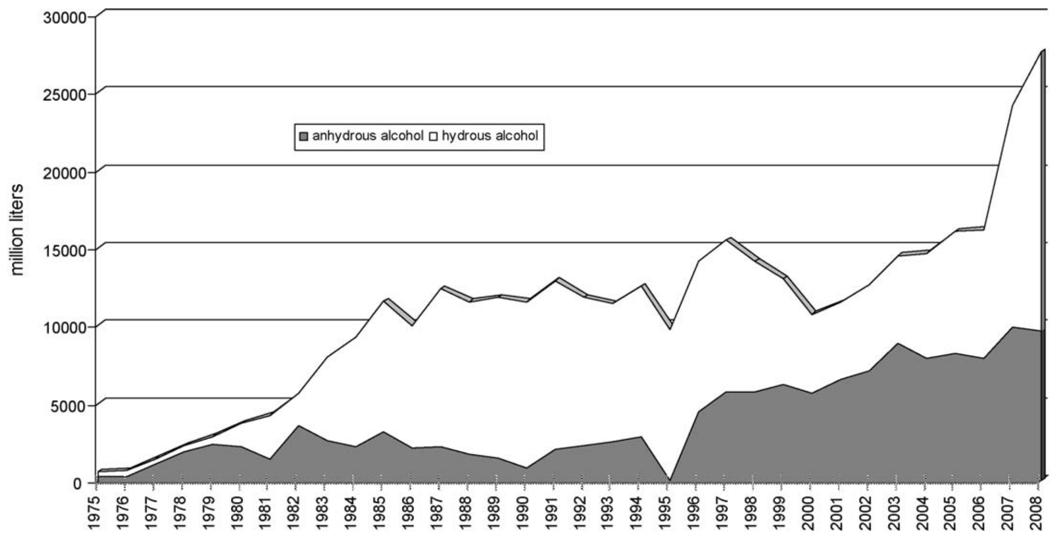
4. Incentives during the Proalcool

From the beginning until 1999, Proalcool benefited from government incentives and their elimination coincided with the deregulation of fossil fuels and sugar–alcohol sectors. In its first stage (1975–1979), there was idle capacity in sugar industry, oil prices were high at the same time prices of sugar were low. So the incentives addressed the construction of distilleries attached to sugar mills. The second oil shock led to a new stage of the program (1979–1985) in which incentives contributed to the construction of distilleries and to the expansion of the automotive sector: new assembly lines should be built to produce cars powered exclusively to ethanol. Between 1989 and 1990, Proalcool suffered its greatest crisis—when ethanol supply was curtailed because sugarcane produced was diverted to sugar production due to favorable international price and demand conditions and imports of ethanol became necessary to meet the fuel demand of the ethanol-fueled cars manufactured in the previous period. During the 1990s, with the extinction of IAA, government intervention ceased and the sugar–alcohol sector was totally deregulated, thus eliminating control of production and marketing, the guarantee of prices and the federal monopoly on exports of sugar. In 2003, a new era started, in which the flex-fuel and tetra-fuel[36] vehicles introduced a distinct dynamic in the automobile sector and the consumption of ethanol, in both forms, anhydrous and hydrous. Graph 2 shows the evolution of ethanol production (both, hydrous and anhydrous) in Brazil after 1975 until today.

Incentives applied during the Proalcool are summarized in the next sections and several features are showed in Table 3.

[23] Abbreviation in Portuguese for Conselho Nacional do Álcool.
[24] Abbreviation in Portuguese for Comissão Executiva Nacional de Álcool.
[25] Abbreviation in Portuguese for Departamento Nacional de Combustíveis.
[26] Abbreviation in Portuguese for Secretaria de Desenvolvimento Regional.
[27] Abbreviation in Portuguese for Departamento de Assuntos Sucroalcooleiros.
[28] Abbreviation in Portuguese for Comissão Interministerial de Álcool.
[29] Abbreviation in Portuguese for Ministério da Integração Regional.
[30] Abbreviation in Portuguese for Departamento de Açúcar e Álcool.
[31] Abbreviation in Portuguese for Secretaria de Produtos de Base.
[32] Abbreviation in Portuguese for Ministério da Indústria, Comércio e Turismo.
[33] Decree 5652/1997, revoked by Decree 3546/2000.
[34] Revoked by Decree 3546/2000.
[35] Abbreviation in Portuguese for Ministério da Agricultura e Abastecimento. From 2001, by the Provisional Measure 2216-37, incorporated the word Livestock in the name, resulting in the current acronym MAPA (Ministério da Agricultura, Pecuária e Abastecimento).

[36] These vehicles may be fueled with gasoline, hydrous alcohol or any blend of the two fuels. The tetra-fuel vehicles can operate using up to four fuels: hydrous alcohol, mixed gasoline, pure gasoline and CNG.



Graph 2. Alcohol Production in Brazil 1975–2009 (l/crop). *Source*: [36].

4.1. Economic policy measures: price setting, subsidies and transferences

CNP (National Council of Petroleum) had a leading role in establishing fuel price policy especially for oil products and ethanol matters.

With two main objectives, of defining maximum and minimum limits for the derivatives, ensuring the competitiveness of domestic products and promoting, as possible, and of assuring uniformity of prices in the national territory, in the 1960s, through parts called "lines", CNP has incorporated the difference between the price of anhydrous ethanol and gasoline "A" in the calculation

Table 3
Incentives for bioethanol in Brazil.

Instrument	Description
Mandatory blend	
• Decree 15/2/1991	• Revoked Decree 59.190 8/9/1966
• Law 8.723/1993	• Blend level–22%
• Law 10.203/2001	• Blend level–24%, can be reduced to 20%
• Law 10.696/2003	• Blend level–25%, can be reduced to 20%
• ResolutionCIMA 37/2007	• Blend level—25%; CIMA is responsible for establishing blend levels
Sustained stocks	
• Decree 83.700/1979	• Alcohol stocks for fuel or chemical industry financed on basis of official parity prices
• Decree 88.626/1983	• CNAL set parameters for Petrobras (responsible for ethanol purchasing) stocks
• Decree 94.541/1987	• Stocks must ensure consumption for two months
• Law 8.176/1991	• Instituted National System of Fuel Stocks (Sinec)
• Decree 238/1991	• SINEC Responsibilities
• Law 9.478/1997	• CNPE establishes SINEC guidelines and Fuel Strategic Stocks Annual Plan fulfillment
• Law 9.847/1999	• ANP monitors SINEC
Tax exemptions	
• Protocol 1979	• Protocol between the government and Anfavea, set the IPI of alcohol at 5%
• Agreement de 2002	• Agreement between the auto industry and MDIC to reduce IPI
• Current Taxation	• There is a tax exemption of VAT and CIDE on alcohol and of CIDE on hydrated alcohol
Cost equalization subsidy	
• Decree-Law 1186/1971	• Established the Price Unified with support of Special Fund of Exportation
• Law 8.393/1991	• Abandoned in 1991 for irregularities that would be favoring some producers
• Decree 4.267/2002	• Proposed operationalization of Subsidy by MAPA and the ANP
• CONSECANA	• Some producers of sugarcane accepted method of payment proposed in Consecana.
Payment and guarantee purchase to ethanol producers	
• Decree 76.593/1975.	• Determines parity price of alcohol based on the ratio 44 l of alcohol per 60 kg of standard sugar
• Decree 83.700/1979.	• CNP determines parity price on net weight of sugar bag on board of truck at mill and/or distillery
• Decree 88.626/1983.	• Authorized passing to Petrobras funds from by the costs incurred with FER*
• Decree 94.541/1987.	• Authorized passing to Petrobras funds from by the costs incurred with PPE
• Ordinance MF 463/1991.	• Ministry of Economy, liberalizing prices
• Ordinance MF 294/1996.	• Liberalized prices of anhydrous alcohol in mills after May 1997
• Resolution CIMA 15/1999.	• Suspended payment on hydrated ethanol
Financing	
• Decree 76.593/1975	• CMN defines sources of funds. Financing and expenses of Proalcool-banking system. R&D funding from ethanol trading.
Economic policies measures	
• Law 10453/2002	• Provides subsidies on the price and the transportation of alcohol fuel.
• Decree 4353/2002	• Regulates law 10453/2002.

Note: *Abbreviation in Portuguese for Fundo Especial de Reajuste de Estrutura de Preços de Combustíveis e Lubrificantes.

of prices of derivatives in the country. In 1979 with the specific objective of promoting the replacement of oil, the CNP introduced an additional "line" in the composition of the price of derivatives, equivalent to 12.5% of the CIF price of imported oil, whose collection was applied to reinforce implementation of Proalcool.

The economic measures implemented by the end of that year, intensified by the second oil shock led to the creation of a specific exchange rate for the sector, denominated "oil-dollar". The complement of the difference between actual exchange rate of the dollar and oil-dollar should be made by the CNP. However, this system was not fully developed and Petrobras carried the loss. Then, to balance out the relationship between the National Treasury and Petrobras, in 1981, an "Oil Account" was established. In 1984, the Account was divided into Oil Account, "Oil Derivatives Account" and "Alcohol Account". That same year, all "lines" constituents of fuel prices structure were extinguished and the IOF (tax on financial operations) rate on oil imports was zeroed. New mechanisms, called FUP[37] (freight for price standardization) and FUPA[38] (freight for alcohol prices standardization), to allow for national price uniformity were introduced. The Alcohol Account was composed by the whole FUPA revenue besides FUP partial revenue; valorization of stocks held by Petrobras, and outcome of MTBE sales [52]. This Account covered the costs of storage and marketing of anhydrous ethanol incurred by Petrobras and accrued surplus until mid 1985 when it started to accumulate negative balances [53].

Law 9478/1997, enacted to start the liberalization of Brazilian fuel market, and to introduce competition and market values, provided for the liquidation of the Oil, Alcohol and Derivatives Accounts (art. 74). Through the Interministerial Ordinance no. 3 of the Ministries of Finance and of Mines and Energy, in 1998, FUP and FUPA were extinct and the Parcel for Specific Price (PPE[39]) was created, as cushion between costs and prices. This parcel resulted from the balance between the actual billing price of all products delivered to the distributors and the Petrobras' actual costs for all products. With the advancement of the liberalization process, the collection of PPE did not reflect the new industry model, because it was applicable only to Petrobras during the transition period, while it retained functions previously held as monopoly on the import of derivatives. Thus, from 01 January 2002 PPE was extinguished and the Contribution for Intervention in Economic Field on Fuel (CIDE[40]) was created by Law 10336/01 in order to meet the extinction of PPE and ensure isonomy of taxation for domestic and imported products [54,55], as well as to collect funds for several purposes, such as road system investment, environmental protection and subsidies for ethanol and LPG. It is a fixed payment, per unit of product, charged to producers, makers and importers of gasoline, diesel, kerosene, LPG, fuel and ethyl alcohol in the operations of importation and marketing of these products in the domestic market.

Under the liberalization environment, the opportunity costs for ethanol became strongly related to the behavior of the international oil market, especially for gasoline. As a consequence, concerns emerged regarding stability of the productive sector, and Law 10453 of 2002, established subsidies, from funds collected by CIDE, to prices and to the transportation of domestic ethanol. Based on this law Decree no. 4353/2002, was enacted, regulating such measures as: equalization of raw materials production costs; purchase and sale of ethanol fuel; tools to support production flow by means of premiums to be paid up to the limit defined by the volume of own production capacity; early offer of guaranteed prices through the promise of future purchase and sale of ethanol, allowing for exercising product delivery option; funding the storage of product, with or without option to purchase; and funding for issuing rural production credit notes [56,57]. The MAPA became responsible for implementation of these measures, subject to prior resolution of CIMA, which should propose to the National Monetary Council the regulation of credit lines needed for that purpose, stating the basic conditions of funding.

4.2. Cost equalization

The subsidy for cost equalization of sugar and ethanol production was created in 1971[41], before the start of Proalcool, under the Policy of National Price Equalization for Sugar and Alcohol, initiated previously. This mechanism offset the production costs of sugarcane and sugar in the North-Northeast that were higher than those of the Center-South. This subsidy was replaced in 1991 by a system of differentiated rates of the Tax on Industrialized Products (IPI): 18.0% in Sao Paulo, 9.0% for the remainder of the Center-South and 0% for the Northeast (plus an additional payment of 25% on ethanol produced in the Northeast) [58]. The grant was redefined by CIMA in 1998 as Program of Cost Equalization. In 1999, this allowance was temporarily suspended due to irregularities that benefited a few producers. However, in the same year it was reenacted by CIMA and extended to more states [59]. In 2002, the operationalization of subsidy for cost equalization was devolved to MAPA and ANP but it was not applied again. Table 3 summarizes the legislation for this incentive.

After liberalization of the sugar–alcohol sector, the economic agents involved in the chain have adapted to the new dynamics of the market, creating the Consecana[42] model in 1999. Currently, 72% of sugarcane growers in the Central-South[43], and 42% in the North-Northeast[44] region follow the parameters of Consecana [60]. These parameters determine the price to be paid to farmers according to the sucrose content.

According to Ministry of Development, Industry and Foreign Trade [61], the sugar–alcohol sector has 370 production units, of which 115 produce ethanol, 15 produce sugar and 240 produce sugar and fuel ethanol. Among ethanol-producing plants, 89 are located in the Northeast and are responsible for 9% of production, while 281 are concentrated in the Central-South and hold 91% of the production of fuel ethanol [62].

4.3. Mandatory blend

The first experience with mandatory blends happened in 1931, when the Vargas Government defined a 5% of ethanol to be added to imported gasoline (Table 3). In 1938, the mandatory blend was extended to national gasoline and the ethanol share was freed up to the limit of necessity (e.g. the Second World War effort), having achieved, in some situations, 46% [63,64]. In 1966, to compensate for the sharp decline in sugar prices on the world market,

[37] Created in 1984 and abolished in 1998 (Ordinance MF/MME 3/98). According to ANP (2001) [51]: "It was designed to cover the difference between the CIF price of imported oil and derivatives and the prices set by government for these products, costs to import foreign oil, transportation costs and associated costs and insufficient collection of FUPA".

[38] Created in 1984 and abolished in 1996 (Ordinance MME 114/96). According to ANP (2001) [51]: "It was designed to cover costs of transportation and related costs of fuel alcohol, differences in price of product, operating and financial costs for carrying stocks, as well as Petrobras management costs on the volume of alcohol it marketed".

[39] Abbreviation in Portuguese for Parcela de Preços Específica.

[40] Abbreviation in Portuguese for Contribuição de Intervenção no Domínio Econômico.

[41] This subsidy existed but by a different mechanism since the 1950s: Resolution 619/1951, Law 4870/1965, Decree – Law 308/1967 (Table 2).

[42] The CONSECANA (Council of producers of sugarcane, Sugar and Alcohol) is an association formed by representatives of the industries of sugar and alcohol and growers of sugarcane, to organize the relationship between both parties.

[43] States of: MG, ES, RJ, SP, PR, SC, RS, MT, MS.

[44] States of: AC, RO, AM, PA, TO, MA, PI, CE, RN, PB, PE, AL, SE, BA.

Table 4
Taxation per liter of fuel produced, consumed and traded (USD/l and %).

	PIS/PASEP	COFINS	CIDE	ICMS
Petrol	US$ 0.0216	US$ 0.0999	US$ 0.1301	20–31%
Hydrous alcohol	0.65% on producer, 1.46% on distributor	3% on producer, 6.74% on distributor		12–30%
Anhydrous alcohol	0.65% on producer	3% on producer		
Biodiesel	Between US$ 0 and 0.0018	Between US$ 0 and 0.0832		General rule
Diesel	US$ 0.0122	US$ 0.0565	US$ 0.0325	12–17%

Source: [68].

coinciding with severe recession in the Brazilian domestic market, government broadened and fixed the limit up to 25%. In 1993 the cap of the blend was 22%, a limit increased, afterwards, to 25%. Currently, according to CIMA the proportion is at 25%.

Gasoline surpluses have occurred since the creation of Proalcool [36]. These surpluses were most significant between 1980 and 1995, though a recovery in petrol consumption initiated in 1987, lasting until 1998. From 1995 to 1998 consumption of gasoline equalized production. Thenceforward surplus generation oscillated until 2003 when it stabilized at a higher level. By the end of 2007, production of gasoline was at 22.2 billion liters and consumption at only 18.6 billion liters. Between 1970 and 2007, 333.5 billion liters of ethanol were used as fuel, equivalent to 216.8 billion liters of gasoline, generating positive economic impacts [36].

4.4. Tax exemptions

This kind of incentive was aimed mainly at the automobile sector and at the hydrous ethanol. The National Association of Manufacturers of Motor Vehicles (ANFAVEA), through a protocol signed with the government in September 1979 started production of cars fueled exclusively with ethanol. The Government, in turn, reduced the IPI (Tax on Industrialized Products) from 11% to 5% for ethanol-fueled cars. It was also granted a reduction of IPVA (Tax on Property of Motor Vehicles) and exemption from the Single Tax on Liquid Fuel [53]. In 1980, 300,000 vehicles were produced, in 1981, 350,000 and 400,000 in 1982. Indeed, sales of ethanol-fueled cars increased from 3114 to 566,482 units between 1979 and the period preceding the Proalcool crisis (1989–1990) [65]. After this shock, sales of ethanol-only cars have plummeted and the problem of consumer confidence in such vehicles was never restored, whereas ethanol fuel option was only able to make a comeback by the introduction of flex-fuel vehicle in 2003. Sales of these vehicles between 2003 and 2007 increased from 48,000 to 1,995,000 [66]. Flex-fuel and ethanol-only vehicles with engine cylinders no larger than 1000 cc enjoy, additionally, a lower IPI (Table 3). The situation of relative fuel prices incentives may ensue an imbalance in the production of food as well as need to further increase export of gasoline impacting the existing oil refining structure [67]. The positive economic effect of the introduction of flex-fuel vehicle, allowing consumer to choose the most favorable fuel however, is diminished by sacrificing thermodynamic efficiency and by the unbalance between increases in the purchase of such vehicles, without corresponding adjustments in the urban infrastructure.

Until 1996, tax exemptions on cars using ethanol were accompanied by the set up of lower prices for ethanol than gasoline. Consumer price for hydrous ethanol was set at a fixed proportion of gasoline price equivalent to 65%, aiming to offset higher costs and less (20%) efficiency (km/l) of ethanol cars. This percentage was defined by the comparison between calorific value of ethanol (21,146 kcal/l) and petrol (32,250 kcal/l) which shows that a unit volume of ethanol corresponds to 65% of the energy content of gasoline. Higher compression rate possible in ethanol dedicated engines ($12:1 \times 9:1$), partially offsets this difference, allowing for breakeven price relationship up to 80%.

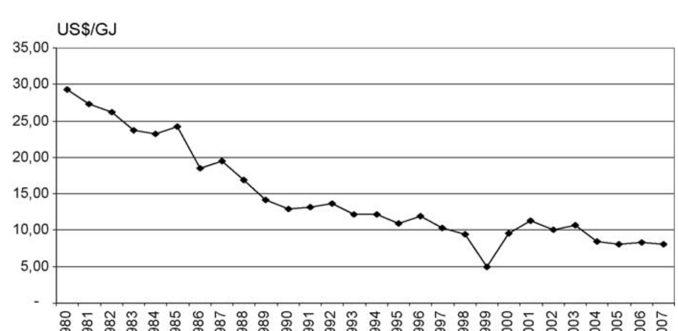
The Ordinance 292/1996 of the Ministry of Finance liberalized the prices of automotive gasoline, including blends (anhydrous ethanol mixed with gasoline) and hydrous ethanol, in wholesale and retail market. Between 1997 and 1999 competition emerged among the agents of the productive chain of ethanol for the appropriation of benefits from the exemption from VAT. Producers claimed that the benefits awarded to distributors should be extended to them. As a result, the transfer was made directly to producers of ethanol between February and September 1999 and was finally extinguished. Nowadays, hydrous ethanol is free from CIDE and anhydrous ethanol is free from CIDE and ICMS (VAT). Table 4 shows taxes applied to each fuel in Brazil.

4.5. Assured payment to producers and guarantee of purchase

At the beginning of Proalcool, payment to producers was determined by IAA. To promote parity between sugar and ethanol production in mills with attached distillery, IAA used to price ethanol based on standard sugar. From 1979 until 1990, price setting procedure became joint responsibility of IAA, CNP and the Ministry of Finance. An 1996 ordinance determined that anhydrous ethanol should be market priced (Table 3). In November 2008, the price paid to producers of hydrous ethanol was US$ 0.3269/l and to the producers of anhydrous ethanol, US$ 0.3869/l both already under free market.

In addition to payment determined by the government until the end of the 1990s, Petrobras has been responsible for buying the produced volume of ethanol. The accounts were balanced while the sales of anhydrous and hydrous ethanol were not significant, inasmuch anhydrous ethanol used to generate surplus whereas hydrous ethanol was subsidized. The increase in consumption, exceeding supply, led to an imbalance, requiring import of ethanol. Concurrently, gasoline surpluses were being exported at lower prices than the imported ethanol [69]. The deficit lasted for at least eight years: between 1988 and 1996, in the case of hydrous ethanol, and from 1986 to 1995, in the case of anhydrous ethanol [36]. In 1995 Proalcool was reassessed.

Payment to ethanol producers has been decreasing since the beginning of the program (Graph 3), due to: technological



Graph 3. Payment to alcohol producer in Brazil related to calorific content—1980–2007. *Source*: [72]. Note: data (1980–2005) from MACEDO, I.C. (isaiasmacedo22@aol.com) Email to: Julieta Puerto (julietapuerto@iee.usp.br). Data (2006–2007) based on price index-CEPEA-ESALQ

Table 5
Investments in Proalcool by Brazilian government until 1985.

Year	Million USD_{1986}
1976	136
1977	891.4
1978	878.20
1979	924
1980	1030
1981	1841
1982	835.4
1983	509.8
1984	963.6
1985	353.1
Total	8364

Source: [76].

advances, which helped to introduce new varieties of cane; efficiency achieved in the industrial process (CTC[45] Programs of Copersucar[46] and of Planalsucar); and good management practices in the production of sugar and ethanol, as well as in the logistics and transport of sugarcane [70]. The fall in prices was propitiated by a continued use of production factors. Although capital concentration led to economies of scale in production of ethanol, negative consequences also arose such as the quality of employment generated in the sector, which remains poor. The seasonal migration of labor is very common in mills and distilleries in several regions of Brazil. Labor practices and events not compatible with human rights requirements, such as slave and child labor, have also been registered [71].

4.6. Stocks policy

The maintenance of stocks coexisted with the guaranteed purchase of distilleries' production. Stocks were considered essential not only to control supply but also to assure price levels consistent with the desired demand [73]. Stocks were formed during the harvest season, with prices set by the government being implemented during the year. In 2003 fears of a new supply crisis of ethanol were still mentioned and the idea that the government should consider funding lines to ensure product storage and distribution for 12 months was advocated [74]. Currently, stocks of ethanol integrate the Annual Plan of Strategic Fuel Stocks under responsibility of ANP. Details are presented in Table 3.

4.7. Funding

Funding was critical to maintain and encourage the production of ethanol fuel. Since the creation of Proalcool the funds encouraged the use of sugarcane, cassava and other materials, seeking also an increased agricultural productivity, by modernization and expansion of existing distilleries, or by installation of new mills, either autonomous or attached to sugar mills. After 1986 subsidized financing has been suspended, and then all funds have been obtained in the market, like any other industrial activity [75]. Dedicated financing was terminated before sector deregulation, helping to consolidate production in distilleries, before ethanol was exposed to competition with other fuels. Table 5 shows investments made by Brazilian government since starting of Proalcool until 1985.

Although funding has been primal to the development of Proalcool, this policy resulted in concentration of land and consolidation of sugarcane monoculture. This outcome was reinforced by the effect of scale of production, the search for greater autonomy in securing supply of raw material, and the increase in production quotas, as happened in the second stage of Proalcool, when annual production increased from 2 to 10.7 million liters.

5. The role of Petrobras in Proalcool

When Proalcool was created, the government gave the program the dual purpose of replacing gasoline, very expensive due the first oil shock, and to regulate the stability of the sugar industry. As at the beginning of the 20th century, the international sugar prices were experiencing a severe drop, after a lasting rise, and it still represented one of the most important export products of the country. There was already a long tradition of using the ethanol as fuel in Brazil and considerable installed, idle capacity, of distilleries attached to sugar mills (mainly in the Northeast). There was the benefit of long term experience. However, differently from the previous strategies, the Proalcool amounted to much larger scale and new objectives. It established support for autonomous distilleries (Center-South), a package of incentives for the modernization and expansion of the existing production and storage structure, and stimulus for research[47] on exclusively ethanol fueled engines, since the use of pure hydrated ethanol in vehicles was envisioned.

The role of Petrobras in the development of bioethanol and its integration in the Brazilian energy mix was essential and historical [77]:

> The participation of Petrobras was decisive in building of Proalcool since its launch in the 70s until today. The company participated with logistics, marketing, technology and capital. In the production, had an early involvement with alcohol from Curvelo plant, in Minas Gerais, using cassava as raw material, but the experiment didn't last.

In the first phase of Proalcool (1975–1979) there was a clear distinction between the more market oriented vision, defended by the sugarcane sector of Sao Paulo, and the vision that called for greater government participation. Government intervention advocates, however, were divided among those asking, with the support of the Northeastern mill owners, to enhance the role of MIC/IAA, and those in favor of MME/CNP/Petrobras. At the time, presence of Petrobras was weakened in this dispute and it had its participation limited to the retailer role of its subsidiary Petrobras Distribuidora. Nevertheless, there was an attempt to impose Petrobras participation, as established by Decree 75966 of July 1975:

> § 3° The production of anhydrous ethanol for blending fuel will be sold by the Institute of Sugar and Alcohol to Petroleo Brasileiro S.A., in the amounts and locations of mixture set in the plan treated in this article, a unit price equal to the sales price of automotive gasoline in the tanks of the distributors, minus the expenses of mixing, in the form established by the Council for Economic Development.

However this was integrally revoked by the Proalcool decree, only a few months later.

At the end of the first phase, Resolution CNP 18/1978 [78] determined that all distributors, not just Petrobras, were required to purchase ethanol directly from the mills and to transport it up to the mixing centers. Petrobras, however, did not neglect to expand its participation, seeking strategic alliances with ethanol producers

[45] Abbreviation in portuguese for Centro de Tecnologia Canavieira.
[46] Abbreviation in Portuguese for Cooperativa Central dos Produtores de Açúcar do Estado de São Paulo.
[47] Conducted by the Center for Aeronautics Technology in Sao Jose dos Campos-SP, whose participation was intense.

and the automotive industry. For the producers it was securing the guarantee of long-term purchase and to the automotive industry, the uniformity and quality of the mixture. The record production achieved by Northeastern state of Pernambuco in 1978 and the lack of capacity to store and outflow that production to the Center-South revealed the fragility of the existing logistics system. The solution forced the entry of the major company into this segment. Thus, in the second phase of Proalcool, Petrobras was in control of the distribution system of the ethanol in the country, as reported by Santos (1985) [79]:

> Control over this system implies control over: (i) the initial point of the system, that is, the alcohol outflow from the production units; (ii) the collecting centers; (iii) the mixing centers or the distribution basis; and (iv) the transportation system that links the production units, the collecting centers, and the mixing centers. Petrobras does not own mixing centers, and seems unconcerned that it does not. All mixing centers are the property of the Distribution Companies, which include Petrobras Distribuidora. Petrobras own Distribution Company receives the same legal treatment as any private Distribution Company, and operates fairly independently of Petrobras itself.

With the publication of CNP Resolution 17/1980, which regulated the ethanol logistics, distribution and marketing systems and with CNAL Resolution 06/1980, which defined the national storage system and also determined that ethanol should share the same transport and distribution system of oil and derivatives, Petrobras was reinforced in the struggle against the private distribution companies. At the end of 1982, Petrobras presence was essential for Proalcool, partly because it had the highest number of ethanol service stations in Brazil. From the company point of view this was the main role of Petrobras, since 1979 [80]:

> Other measures were taken in the Distribution Area, through Petrobras Distribuidora - BR, such as the first AEHC[48] distribution pumps, launching of the first lubricant suitable for such engines, development, together with CENPES[49], of specific equipment for this purpose as pumps, densimeters, filters and others.
> However the great contribution of Petrobras regarded the transportation and storage of the product. The large number of distilleries, its distance from the consuming centers, seasonality of crops, which required the setting up of buffer stocks which require huge resources of capital and the appropriate storage capacity, finally, the necessity and difficulty of completing the cycle of distillery to the tank of the vehicle or the mixing centers were, in fact, crucial to the viability of the program.

Although having discharged itself successfully from the legal and strategic incumbency to collect all ethanol produced anywhere and to make it available to all service stations in the country, since late 1970s, several issues, including difficult relationship with producers and non-collected credits, left a sour image and perception of ethanol business in the company's culture and memory. However, in 2003, from the perception of the existence of potential international demand for biofuels, especially ethanol to meet Kyoto Protocol goals, from specific expressions of interest for imports by Japan, and the opportunity foreseen from high production costs in U.S. and Europe, sustained with high import tariff barriers, the company, through the Gas and Energy Division created two internal working groups, on ethanol and biodiesel, officially resuming its participation in this segment. As Petrobras (2008) [77] emphasizes:

> From this demand and the possibility of the country to implement a national program for the production of biodiesel, two working groups were created by Gas and Energy Division, one on ethanol and other on biodiesel. The groups concluded in mid-2004 that biofuels would effectively represent, in short, a large share of fuels in use in Brazil and abroad, and that Petrobras should enter the market, driven by three reasons:
> (1) The business opportunity, especially for its logistics and technical capacity;
> (2) Because other companies, especially from international capital, occupy space in the production of biofuels in Brazil, and Petrobras is not yet involved;
> (3) And also because Petrobras can add value to its corporate identity and image, due to the increasing demands of public opinion related to the reduction of emissions of the greenhouse gases.

6. Conclusions

The trilemma between producing either fossil energy or renewable energy (including biofuels), or producing food and ensuring its distribution to satisfy human needs in a globalized market is already present since the late 19th century. The winner option seems to have been determined by the maximum economic surplus generation. However, how much of the objective conditions for this outcome were related to the natural attributes of the resources and how much was built socially and institutionally is difficult to determine. Of course, intrinsic characteristics of oil, such as net available energy, seem to have been of paramount importance. But the industrial organization framework built around the oil interest cannot be neglected. It is amazing that Ford envisioned that ethanol, produced via sugar and cellulosic content of crops, could be a source of decentralized supply of fuel for auto owners. Ford translated expectations in investments in pure ethanol engines and in the first flex-fuel cars, a century ago. But, after a few years of auto industry with ethanol being perceived as a real option, oil was the winner. The chances of ethanol survival hinged on the ability of its stakeholders to influence the Government structure, in order to secure incentives, market share, subsidies and technological development required to stay in the game.

The possibilities of ethanol fuel, as perceived in France, Germany and U.S., in the 1920s, inspired the Brazilian sugarcane elite to pursue a new opportunity to rescue sugar production structure, beleaguered by loss of international market share and price volatility. Political organization of their interests promoted the institutionalization of Governmental agencies, which finally were consolidated under IAA. The Institute acted as broker to assure logistics, market share and to establish prices and production quotas to optimize allocation of resources for production of sugar or ethanol in order to maximize economic surplus in favor of sugarcane elite. From the State perspective, beyond accommodating the interests of a powerful political group, this policy provided the benefits of stabilizing foreign currency income from sugar exports and saving gasoline imports. Hence, more than a fuel industry per se, ethanol became a by-product as well as a regulatory buffer of the sugar industry as imposed by the international sugar market conditions. Second World War supply and price shocks of oil products enhanced the role of ethanol as strategic good, hence fostering investments in technology, production capacity, logistics, alongside with price incentives. Consequently, ethanol almost acquired autonomous market status. This window of success was, however, ultimately frustrated by the

[48] Abbreviation in Portuguese for Álcool Etílico Hidratado Combustível.
[49] Abbreviation in Portuguese for Centro de Pesquisa e Desenvolvimento Leopoldo A Miguez de Mello (Petrobras Research Centre, Rio de Janeiro, Brazil).

generalized critical environment: lack of imported inputs, coastal transport sabotage threats and fortuitous external high sugar prices. During the post-war period until the oil shocks of the 1970s, while oil prices stabilized at a low level plateau, the mandatory blending remained in force, but the range, 5–25%, was adjusted according to the international sugar market performance, and later, also to the gasoline market interests, marking thus an ethanol trend towards ostracism. This environment, while keeping substantially stagnant the Northeastern sugarcane industry, provided the conditions for the emergence of the Southeast sugarcane agribusiness hegemony.

Nevertheless, five decades of experience with ethanol, at all levels, agricultural, industrial, logistics, regulation, incentives, institutional framework and coordination, were essential for the establishment of Proalcool, clearly conceived as an energy policy, even though retaining necessary coordination mechanisms with the sugar industry interests.

Proalcool, as a response to the oil shocks, of 1973–1979, was structured around a comprehensive framework comprising: (a) economic policies (price setting, subsidies, transferences); (b) increasing mandatory blending; (c) cost equalization; (d) tax exemptions; (e) assured payment to producers and guaranteed purchase; (f) sustained stocks; (g) funding for agriculture, industry, logistics and vehicles. A marked difference of Proalcool from the first five decades was the role of Petrobras, and the introduction of pure, hydrated, ethanol vehicles. Petrobras was one major agent of Proalcool since 1979 on participating with logistics, marketing, technology and capital. In this period automotive industry and Government, in "co-responsibility", established a timetable for substituting ethanol-fueled for gasoline-powered cars. In 1980, the technology for ethanol vehicles had already been successfully developed. Higher costs of ethanol cars, as compared to gasoline cars, were offset by tax exemptions. After 1980, ethanol cars sales skyrocketed and this favorable environment lasted until 1990, when Proalcool suffered its worst crisis, a supply shock, as increasing international sugar prices prompted industry to divert raw material to sugar instead of ethanol production. Ethanol had to be imported. The consumers' confidence in ethanol cars was never restored and ethanol only recovered in 2003, when the new flex-fuel automobiles were launched.

The consolidation of ethanol fuel in Brazil was possible due to implementation of a comprehensive public policy, capable of coordinating issues as:

- Organization and development of feedstock production chains including research and development for agricultural zoning and crops improvements; integration of productive arrangement; funding for land use, and coordination with producers for outflow of feedstock.
- Mechanisms of stabilization of the production chains constantly threatened by the behavior of the prices of oil and of sugar.
- Establishment of industrial phase with: scale and scope agreements; research and development for improving the efficiency of the process and the use of by-products; funding for the installation and operation of plants; mechanisms of guaranteed market and for outflow of ethanol.
- The role of fuel industry providing availability of infrastructure, comprised by storage, blending, transport capacity, quality control, maintenance of stocks and coordination for access to retail and wholesale market.
- Marketing with a price policy rewarding costs of production factors.
- Consolidation of the biofuel consumer segment through regulatory and tax incentives that allowed for the gradual adaptation of artifacts and equipment, imported, manufactured or existing.
- Mechanisms for certification standardization of commodities.

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